PCT/IB00/00256

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT **NOTIFICATION OF ELECTION** (PCT Rule 61.2)	To: Commissioner US Department of Commerce United States Patent and Trademark Office, PCT 2011 South Clark Place Room CP2/5C24 Arlington, VA 22202 ETATS-UNIS D'AMERIQUE in its capacity as elected Office
Date of mailing (day/month/year) 01 November 2000 (01.11.00)	
International application No. PCT/IB00/00256	**Applicant's or agent's file reference** W/D/126
International filing date (day/month/year) 10 March 2000 (10.03.00)	**Priority date** (day/month/year) 10 March 1999 (10.03.99)
Applicant BOOYSEN, Andre et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

05 October 2000 (05.10.00)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was [ ] was not made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer Zakaria EL KHODARY Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

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INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference W/D/126	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/IB 00/ 00256	International filing date *(day/month/year)* 10/03/2000	(Earliest) Priority Date *(day/month/year)* 10/03/1999
Applicant DEBEX (PROPRIETARY) LIMITED et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 4 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.
   [ ] filed together with the international application in computer readable form.
   [ ] furnished subsequently to this Authority in written form.
   [ ] furnished subsequently to this Authority in computer readble form.
   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

   [ ] the text is approved as submitted by the applicant.
   [X] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 10

   [X] as suggested by the applicant.
   [ ] because the applicant failed to suggest a figure.
   [ ] because this figure better characterizes the invention.

   [ ] None of the figures.

Box III TEXT OF THE ABSTRACT (Continuation of item 5 of the first sheet)

The abstract is modified as follows:

X-ray imaging apparatus is provided for generating a composite image of a subject by moving a radiation source (12) and a camera array (122) relative to the subject. A drive mechanism (22) generates clock signals which are used to synchronise the operation of the camera array with the movement thereof, and the composite image data which is generated is stored for display and further signal processing. Control means move the radiation source (12) and the camera array (122) according to the intensity of the imaging beam.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB 00/00256

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A61B6/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 4 179 100 A (STERNGLASS ERNEST J ET AL) 18 December 1979 (1979-12-18) column 4, line 43 -column 5, line 16 column 12, line 46 -column 13, line 4 column 13, line 52 - line 68 column 15, line 62 -column 16, line 15 ---	1,2,8,9,15 12
A	DE 35 03 465 A (MORITA MFG) 1 August 1985 (1985-08-01) page 5, line 20 -page 6, line 19 page 9, line 1 - line 25 -----	1,15

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 June 2000	21/06/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Martelli, L

1

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4179100 A	18-12-1979	DE 2950767 A	25-06-1981
		FR 2471178 A	19-06-1981
		GB 2066016 A,B	01-07-1981
		NL 7909037 A,B,	16-07-1981
DE 3503465 A	01-08-1985	JP 1595851 C	27-12-1990
		JP 2018091 B	24-04-1990
		JP 60160947 A	22-08-1985
		FI 850415 A,B,	02-08-1985
		US 4589121 A	13-05-1986

PATENT COOPERATION TREATY

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Entered	[signature]
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From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

DILSON, David Grant et al.
SPOOR & FISHER
PO Box 41312
Craighall 2024
AFRIQUE DU SUD

SPOOR & FISHER
2001 -05- 1 0
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PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Rule 71.1)

Date of mailing (day/month/year) 04.05.2001

Applicant's or agent's file reference PA129270/PCT	**IMPORTANT NOTIFICATION**	
International application No. PCT/IB00/00256	International filing date *(day/month/year)* 10/03/2000	Priority date *(day/month/year)* 10/03/1999
Applicant DEBEX (PROPRIETARY) LIMITED et al.		

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

   The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

   Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

   For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/	Authorized officer
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Marra, E Tel.+49 89 2399-7235

Form PCT/IPEA/416 (July 1992)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference PA129270/PCT	**FOR FURTHER ACTION** See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/IB00/00256	International filing date *(day/month/year)* 10/03/2000	Priority date *(day/month/year)* 10/03/1999
International Patent Classification (IPC) or national classification and IPC A61B6/00		
Applicant DEBEX (PROPRIETARY) LIMITED et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 8 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

   I ☒ Basis of the report
   II ☐ Priority
   III ☒ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   IV ☐ Lack of unity of invention
   V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   VI ☐ Certain documents cited
   VII ☒ Certain defects in the international application
   VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
05/10/2000	04.05.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Schießl, W Telephone No. +49 89 2399 7436

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

   Description, pages:

   1-25 as originally filed

   Claims, No.:

   1-15 as originally filed

   Drawings, sheets:

   1/12-12/12 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).

   ☐ the language of publication of the international application (under Rule 48.3(b)).

   ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   ☐ contained in the international application in written form.

   ☐ filed together with the international application in computer readable form.

   ☐ furnished subsequently to this Authority in written form.

   ☐ furnished subsequently to this Authority in computer readable form.

   ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   ☐ the description, pages:

   ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

III. Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

1. The questions whether the claimed invention appears to be novel, to involve an inventive step (to be non-obvious), or to be industrially applicable have not been examined in respect of:

   ☐ the entire international application.

   ☒ claims Nos. 9-11, 15.

because:

☐ the said international application, or the said claims Nos. relate to the following subject matter which does not require an international preliminary examination (*specify*):

☒ the description, claims or drawings (*indicate particular elements below*) or said claims Nos. 9-11, 15 are so unclear that no meaningful opinion could be formed (*specify*):
see separate sheet

☐ the claims, or said claims Nos. are so inadequately supported by the description that no meaningful opinion could be formed.

☐ no international search report has been established for the said claims Nos. .

2. A meaningful international preliminary examination cannot be carried out due to the failure of the nucleotide and/or amino acid sequence listing to comply with the standard provided for in Annex C of the Administrative Instructions:

   ☐ the written form has not been furnished or does not comply with the standard.

   ☐ the computer readable form has not been furnished or does not comply with the standard.

V. Reasoned statement under Article 35(2) with r gard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

   Novelty (N) Yes: Claims 4-7, 12-14

	No:	Claims	1-3, 8
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1-8, 12-14
Industrial applicability (IA)	Yes:	Claims	1-8, 12-14
	No:	Claims	

2. Citations and explanations
   see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

Section III

1 The intended limitations are not clear from claims 9-11, as no functional relationship of the respective features of claims 9 and 10 with any control of the drive means as required in claim 1 is specified. The same applies to claim 11, wherein no control of the drive means based on the intensity of the imaging beam is established. The more so, as claims 9-11 refer back to any of the preceding claims, thereby introducing further combinations of control / drive means features.

2 In claim 15, reference is made to the description and drawings such that the intended limitations are completely unclear. Note that any reference to the specification is limited to exceptional cases (PCT Guidelines PCT/GL/3 III, 4.10).

3 Thus, the International Preliminary Examining Authority considers that no meaningful opinion can be formed on the subject-matter of claims 9-11 and 15 (Article 34(4)(a)(ii) PCT).

4 It should however be noted that the combinations of features of claims 9-11 regarded as independent functional units of the control means do not appear to meet the requirements of Article 33 PCT, as an image compensation for the X-ray intensity according to claim 9 is disclosed in D1 (col. 13, ll. 52-68, fig. 15) and a synchronization of the drive means and the data acquisition of the camera array as defined in claims 10 and 11 appears to be known in dynamic imaging involving detector arrays.

Section V

1 Reference is made to the following document (D) cited in the International Search Report:

D1: US-A-4 179 100 (STERNGLASS ERNEST J ET AL) 18 December 1979 (1979-12-18)

2 Novelty (Article 33(2) PCT)

2.1 The present International Application does not meet the requirements of Article 33(2) PCT since the subject-matter of claim 1 is not new in that document D1 anticipates an imaging apparatus comprising all features of claim 1 (col. 12, l. 46 to col. 13, l. 68, figs. 13-15), in particular a control means (cf. VIII, 2 below) responsive to the image signals / composite image data to control the operation of the drive means according to the intensity of the imaging beam (col. 13, ll. 57-65).

2.2 Dependent claims 2, 3 and 8 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of novelty, since D1 anticipates further

- an x-ray source and cameras as recited in claim 2 (col. 13, ll. 5-10),
- overlapping fields of coverage according to claim 3 (in that light from a transverse overlapping region of the scintillator means at the border of adjacent fiber optic means 258 and 260 will be collected; col. 13, ll. 5-31, fig. 14b; cf. VIII, 3),
- a drive control as defined in claim 8 (cf. item 2.1 above).

3 Inventive step (Article 33(3) PCT)

The remaining dependent claims do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of inventive step, since

- the specific shape / overlap of the fields recited in claim 4 is a slight constructional change (cf. 2.2 above),
- a compensation algorithm according to claims 5-7 and a filter technique as defined in claims 12-14 appear to be known by the person skilled in the art of dynamic imaging.

Section VII

1 Independent claim 1 is not in the two-part form in accordance with Rule 6.3(b) PCT.

2 The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

3 Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in document D1 is not mentioned in the description, nor is this document identified therein.

Section VIII

The present international application does not meet the requirements of Article 6 PCT:

1 In claim 1, the term "the intensity of the imaging beam" can be interpreted as both the intensity at any point of the radiation beam between source and detector, for instance beyond the object, and the detected intensity comprised in the image signals and/or the image data. The same applies mutatis mutandis to the terms "variations in the intensity, effective intensity, intensity fluctuations" used in claims 8 and 9.

2 The definition of the control means in claim 1 appears to cover essentially a control of the drive means **using the intensity of the imaging beam** (cf. item 1 above), whereby it is not required that said intensity is derived from the image signals / image data. The control means is solely defined to be responsive to the image signals (and/or the image data) in an unspecific way like the main control unit of any imaging apparatus.

3 The term "overlap" used in claims 3 and 4 covers portions of a single or two distinct fields of coverage (scintillators), which overlap perpendicular to the incident beam as well as an overlap as defined in claim 9 showing a gap between these portions. As far as the orientation is concerned, it is annotated that the direction of movement of the camera array can relate to either the longitudinal or the rotational movement of the source / detector relative to the patient.

4 The embodiments of the claimed invention described on pages 4, last paragraph et seq. and shown in figures 1-18 do not fall within the scope of the claims, since no active control of the drive means according to image signals, composite image data or imaging beam intensity as required by claim 1 is mentioned. On the contrary, a compensation of the images for scan speed variations and X-ray intensity fluctuations is shown (pp. 16-21 of description, whereby the origin of X-

ray intensity signal is not apparent), so that the subject-matter of at least claim 1 is not supported by the description. Moreover, this inconsistency between the claims and the description leads to doubt concerning the matter for which protection is sought, thereby rendering the claims unclear.

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 :
A61B 6/00

A1

(11) International Publication Number: WO 00/53093

(43) International Publication Date: 14 September 2000 (14.09.00)

(21) International Application Number: PCT/IB00/00256

(22) International Filing Date: 10 March 2000 (10.03.00)

(30) Priority Data:
99/1927 10 March 1999 (10.03.99) ZA

(71) Applicant *(for all designated States except US)*: DEBEX (PROPRIETARY) LIMITED [ZA/ZA]; Corner of Crownwood and Booysens Reserve Road, 2092 Crown Mines (ZA).

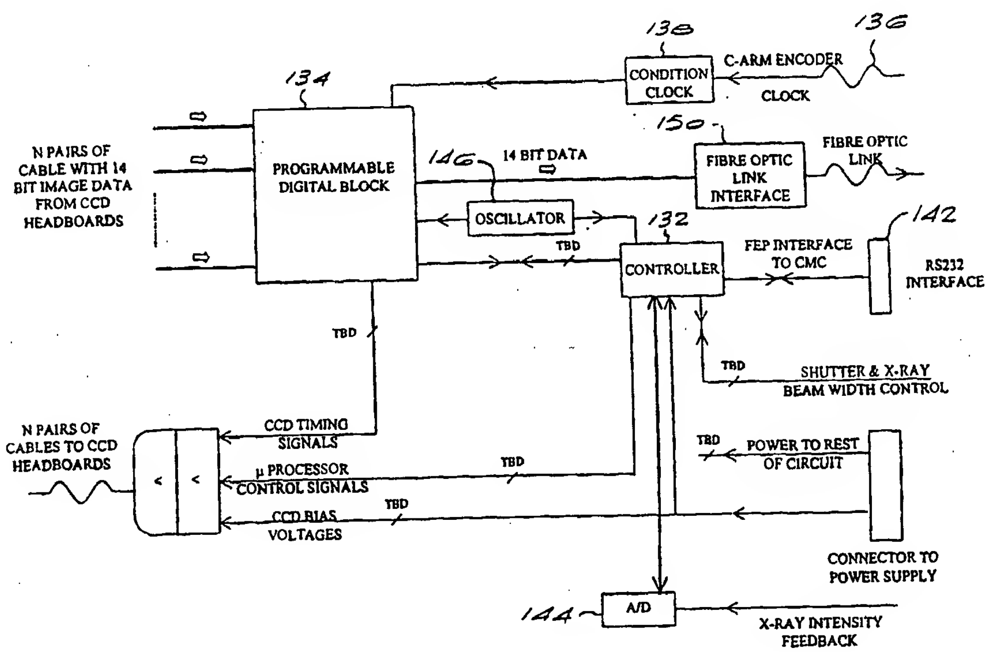
(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: BOOYSEN, Andre [ZA/ZA]; 40 Janet Street, Florida, 1724 Roodepoort (ZA). POTGIETER, Johannes, Hermanus [ZA/ZA]; Plot 1, Treesbank Agricultural Holdings, 1685 Midrand (ZA). VAN LOOY, Paul [ZA/ZA]; 8 Arend Avenue, Windsor Glen, 2194 Randburg (ZA). SOUSA, Carlos, Manuel, De Seabra [ZA/ZA]; 36 Gorst Avenue, 1401 Primrose (ZA). VERMEULEN, Andries, Gerhardus, Johannes [ZA/ZA]; 60 Vungu Place, 0044 Moreletapark (ZA).

(74) Agents: DE VILLIERS, Christopher, Murray et al.; Spoor and Fisher, Rochester Place, 173 Rivonia Road, Morningside, Sandton, P.O. Box 41312, 2024 Craighall (ZA).

(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: IMAGING APPARATUS



(57) Abstract

X-ray imaging apparatus is provided for generating a composite image of a subject by moving a radiation source (12) and a camera array (122) relative to the subject. A drive mechanism (22) generates clock signals which are used to synchronise the operation of the camera array with the movement thereof, and the composite image data which is generated is stored for display and further signal processing. Control means move the radiation source (12) and the camera array (122) according to the intensity of the imaging beam.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

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CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
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DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

IMAGING APPARATUS

BACKGROUND TO THE INVENTION

THIS invention relates to imaging apparatus which can be used, for example, in radiological applications.

Conventional X-ray imaging apparatus is of limited versatility and is generally unsuitable for use in whole-body imaging of patients at a resolution sufficient for diagnostic purposes. South African patent no. 93/8427 describes a system which is designed to facilitate whole-body imaging of a subject in order to detect smuggled articles such as diamonds concealed on the person of the subject, while at the same time minimising the radiation dose received by the subject.

It is an object of the invention to provide an alternative apparatus which can produce images of medical diagnostic quality at relatively low radiation doses.

SUMMARY OF THE INVENTION

Imaging apparatus comprising:

a radiation source for generating an imaging beam;

a camera array comprising a plurality of cameras responsive to the imaging beam and arranged adjacent one another, each camera having an output for generating image signals;

drive means for moving the radiation source and the camera array relative to a subject;

signal processor means arranged to receive image signals from the data output of each camera and to generate composite image data therefrom;

memory means for storing the composite image data;

output means for displaying an image generated from the composite image data; and

control means responsive to the image signals and/or the composite image data to control the operation of the drive means according to the intensity of the imaging beam.

The radiation source may be an X-ray source and the cameras comprise scintillators and associated charge-coupled devices for generating digital image data signals.

The camera array may be arranged so that fields of coverage of adjacent cameras overlap in a direction transverse to the direction of movement of the camera array, so that the camera array provides full coverage of an elongate imaging zone defined thereby.

In a preferred embodiment, each camera has an active area with a parallelogram shape, with adjacent ends of the respective active areas abutting, so that the coverage of adjacent cameras overlaps in a relatively narrow transition zone extending transversely to the direction of scanning.

The signal processor means preferably comprises a digital signal processor arranged to apply a compensation algorithm to the image data signals to compensate for relative misalignment or distortion of the cameras.

The compensation algorithm may be arranged to compensate for misalignment of each image pixel with respect to both x- and y- axes, the y-axis corresponding to the direction of scanning and the x-axis being transverse to the direction of scanning.

Preferably, the compensation algorithm is arranged first to compensate for errors in the positioning of pixels in the direction of the y-axis, and then in the direction of the x-axis to compensate for unexposed and overlapping pixels in the transition zones between the cameras.

The control means is preferably arranged to measure variations in the intensity of the imaging beam, and to generate drive control signals to vary the speed of the drive means, to maintain the effective intensity at a constant level.

The control means may be arranged to carry out intensity compensation by means of software correction of the image data signals using measured information regarding intensity fluctuations in the imaging beam.

The drive means may have an encoder associated therewith for generating clock signals related to the movement of the radiation source and the camera array, and the control means includes a clock conditioning circuit responsive to the clock signals to generate timing signals which are used to synchronise the imaging operation of the camera array with the movement thereof.

Alternatively, the control means may include a reference clock circuit which is used to generate timing signals for controlling both the operation of the drive means and the camera array, so that the imaging operation of the camera array is synchronised with the movement thereof.

Each camera preferably defines a plurality of imaging pixels, the outputs of at least some of the pixels being combined according to a predetermined scheme to improve the signal-to-noise ratio of the image signals.

In a preferred embodiment, the cameras are adapted to combine the outputs of pixels which are adjacent in the direction of movement of the radiation source and the camera array at the time of generation of the image signals.

The signal processor means is preferably adapted to process the image signals to combine the outputs of pixels which are adjacent in a direction transverse to the direction of movement of the radiation source and the camera array.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described in more detail, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a pictorial view of imaging apparatus according to the invention;

Figure 2 is an end elevation of the apparatus of Figure 1 showing a scanning arm thereof rotated through 90°;

Figure 3 is a similar view to that of Figure 2, showing an alternative application of the apparatus;

Figure 4 is a pictorial view of a radiological installation incorporating the apparatus of the invention;

Figure 5 is a schematic illustration of the arrangement of the X-ray source;

Figure 6 is a schematic illustration of a beam width adjuster for the X-ray source;

Figure 7 is a schematic block diagram of the X-ray detector of the apparatus;

Figure 8 is a schematic illustration of an individual X-ray camera of the detector of Figure 7;

Figure 9 is a schematic illustration of an array of X-ray cameras of the detector of Figure 7;

Figure 10 is a schematic block diagram of a front end processor of the apparatus;

Figure 11 is a block schematic diagram illustrating the hardware and software interfaces of an image pre-processor of the apparatus;

Figure 12 is a block diagram of the image pre-processor;

Figure 13 is a flow chart of the image correction performed by the image pre-processor;

Figure 14 illustrates one image correction performed by the image pre-processor;

Figure 15 illustrates a second image correction performed by the image pre-processor;

Figure 16 shows a flow diagram for determining coefficients to be used during compensation;

Figure 17 is a schematic block diagram of the system manager of the image pre-processing circuitry; and

Figure 18 is a schematic diagram illustrating the state modes of the image pre-processing circuitry.

DESCRIPTION OF PREFERRED EMBODIMENTS

Figures 1 to 3 show three different views of prototype X-ray imaging or scanning apparatus of the invention. The apparatus comprises a head 10 containing an X-ray source 12 which emits a narrow, fanned beam of X-rays towards a detector arrangement 14. The X-ray source 12 and the detector 14 are supported at opposite ends of a curved arm 16 which is generally semi-circular or C-shaped.

A frame 18 mounted on a wall 8 or another fixed structure defines a pair of rails 20 with which a motorised drive mechanism 22 engages to drive the arm linearly back and forth in a first, axial direction of movement. In addition, the drive mechanism comprises a housing 24 in which the arm 16 is movable by the drive mechanism in order to cause the X-ray source and the detector to rotate about an axis parallel with the first direction of movement of the mechanism.

A typical application of the imaging apparatus of the invention is in a radiological installation, such as that illustrated in Figure 4. The imaging apparatus is shown located in a corner of a room which may be a resuscitation area or trauma room of a hospital, for example. Alternatively, the apparatus may be located in a radiological department of a hospital or elsewhere.

Located adjacent to the imaging apparatus is a local positioning console 26, by means of which an operator can set up the required viewing parameters (for example, the angle of the arm 16, start and stop positions, and the width of the area to be X-rayed). A main operator console 28 is provided behind a screen 30 which is used by the operator to set up the required radiographic procedure. The imaging apparatus is operated to perform a scan of a subject 32 supported on a specialised trolley or gurney 34 (see below) and an image of the radiograph is displayed on a screen at the console 28, in order to allow the operator to judge whether a successful image has been acquired.

One or more high quality monitors 36 are provided for diagnostic viewing and are located so that attending clinical staff can study the radiographs being acquired. In addition, a console 38 is provided which forms part of a standard Radiological Information System which permits picture viewing and archiving.

The arrangement of Figure 4 is designed for use in the resuscitation room of a trauma unit, in order to provide fast X-ray images of injured patients. Once a

patient has been stabilised, he or she can conveniently be placed in position, scanned, and wheeled out for further treatment, with the resulting radiograph appearing on the diagnostic screen virtually instantaneously. Due to the low X-ray dose administered by the apparatus, the risk of radiation exposure to staff and patients is reduced.

The various functional aspects of the apparatus will now be described in greater detail.

In order to exploit the potential of the invention for rapid X-ray imaging, a special trolley 34 is provided which is height adjustable and which is provided with an electromagnetic clamping and location arrangement to secure it in position relative to the arm 16 of the scanning apparatus during operation.

Once the trolley has been locked in position, the arm 16 of the apparatus is rotated into the required position and is also locked into position electromagnetically. The shape of the arm defines a cavity which is sufficiently large to surround the body cf a patient supported on the trolley 34.

With the arm 16 locked into position relative to the housing 24 of the drive mechanism and the trolley 34 also locked into position, the drive mechanism is operated so that the apparatus performs a horizontal linear scan. A narrow fanned beam of X-rays irradiates a thin strip across the width of the patient bed as the X-ray source and the detector move from the starting point to the end point of the scan.

A standard position of operation of the apparatus is with the X-ray source 12 uppermost in order to permit the taking of A-P (anterior to posterior) and P-A full body images. The arm 16 can be rotated through up to 90° for different radial/lateral views. The height adjustable trolley 34 is useful for pinpointing specific areas of interest. As an alternative to adjusting the height of the

trolley, the height of the arm assembly could be adjusted instead. With the arm rotated through 90°, erect chest views are also possible, as indicated in Figure 3.

In the prototype apparatus, the width or thickness of the X-ray beam (in the direction of scan) on the detector is determined by a thin slit collimator which is factory preset to less than 10mm. Mounted in front of this slit is a second collimator that determines the length of the rectangular strip (transverse to the direction of scan) to be exposed to X-rays. This length is adjustable from a minimum of 100mm to the full 680mm field of exposure, in addition to a certain amount of offset from the bed centre line. A visible light source provided in the head 10 generates a thin beam, coincident with the X-ray beam, to illuminate the irradiated portion of the subject in use.

Referring to Figure 5, the X-ray source consists of an X-ray tube, X-ray shutter, X-ray filter, coincident light source, collimator and X-ray beam width controller. The X-ray tube 100 generates X-rays and is powered by a high voltage power supply. The X-ray shutter 102 prevents exposure of the patient to X-rays in cases when the tube is provided with power but all the operational conditions are not met, for example during power-up or the ramping up of the scanner arm speed. It also acts as a safety interlock to the control system.

The X-ray filter 104 ensures that the spectrum is filtered to the correct "hardness" by removing "soft" or low energy X-rays which would be absorbed by the patient's body and not contribute to the quality of the image. A light source 106 and an X-ray translucent mirror 108 provide a light beam which is the shape of, and coincident with, the X-ray beam. This indicates the X-ray beam's size and position to the operator.

An X-ray collimator 110 blocks off the unwanted divergent X-rays which are detrimental to image quality, promote scatter and unnecessarily increase the

amount of dose to the patient. The collimator is a thin slit in an X-ray opaque material, which is located at a distance far enough from the X-ray tube to allow approximately a parallel beam of X-rays through. The percentage of non-parallel X-rays is determined by factors such as the slit's width, the slit's depth and the distance from the slit to the X-ray tube's focal spot. The image quality is improved in two ways by using the collimator. It effectively creates a parallel or collimated beam of X-rays and it reduces the instantaneous exposure area.

The degree of beam collimation specifies the angle of divergence of the X-ray beam, or the degree to which the X-rays are parallel. The non-parallel X-rays effectively cause parallax errors which in turn give rise to smear. The degree of collimation therefore determines the amount of image smear as a result of the scanning X-ray technique. The minimum resolution required in the scanning X-ray system determines the amount of smear that can be tolerated and hence the minimum degree of collimation.

A secondary result of the collimated X-ray beam is a very narrow (typically less than 10 mm) instantaneous exposure area. An image is produced through X-rays by irradiating an object and capturing the transmitted rays. The X-rays are differentially absorbed in the object as result of variations in thickness and densities throughout the object. However, a certain amount of the X-rays are scattered isotropically and do not travel straight to the detector. These scattered X-rays do not add to the information in the image, but are rather a source of noise. By utilising a very narrow instantaneous exposure area and correspondingly narrow detector, a minimum of these scatter X-rays are picked up by the detector, thereby reducing the noise in the image. This allows the X-ray dose to be reduced relative to large area exposures, while maintaining the necessary signal to noise ratio.

In some configurations of the apparatus, the useful X-ray beam thickness may be narrower than the actual detector thickness. This could cause unwanted

scattered X-rays to be detected. In order to prevent this, a further collimator or post-collimator, situated between the detector and the patient, could be used to screen off these scattered X-rays, thereby further improving the signal to noise ratio of the system. Such a post-collimator can comprise two strips of high X-ray attenuating material, such as tungsten, placed on either side of the useful X-ray beam in such a way that any scattered X-rays do not reach the detector.

Control of the X-ray beam width is accomplished by means of a beam width controller or shutter mechanism 112, illustrated schematically in Figures 6a, b and c. The beam width controller fulfils similar functions to the collimator in improving image quality, reducing scatter and reducing unnecessary dose to the patient. The X-ray beam width controller 112 controls the width of the X-ray image as well as any offset from the centre of the beam. It is also useful to limit the beam width to the X-ray camera (situated in the X-ray detector, illustrated in Figure 7) to avoid saturation. The prototype beam width controller consists of two geared bars or racks 114 manufactured from an X-ray opaque material and having a T-section. The racks 114 are slidable longitudinally in a channel 116 and are moved into and out of the beam by means of respective pinions 118, which can be connected to electrical motors or to knobs 120 as illustrated, for automated or manual movement, respectively. The exposure area's length can be adjusted from 100 mm up to any desired length (680mm in the prototype).

The X-ray detector 14 is illustrated schematically in Figure 7 and comprises a plurality of X-ray cameras 122, each with an associated CCD headboard 124. Charge Coupled Devices (CCD's) are effective at detecting radiation in the visible wavelength range and converting it to an analogue electronic output signal. They are less effective at detecting X-rays and are damaged by X-ray radiation. Scintillators are therefore employed to convert the X-rays to light. The scintillators cover the whole area over which the X-rays strike the camera. CCD's are limited in size and are extremely expensive. The image area is

therefore covered by multiple CCD'S, the total number being determined by a cost vs. resolution trade-off.

The outputs of the respective CCD headboards 124 are fed to a front end processor 126 which has a fibre optic data link output 128. In the prototype, twelve CCD headboards 124 were interfaced to one front end processor 126. The front end processor (FEP) 126 is mounted in the C-arm 16 in close proximity to the CCD headboards, and connectors on the front end processor 126 are spaced to facilitate as short as possible an interface to the CCD headboards.

The arrangement of a single camera is illustrated schematically in Figures 8a and b. The camera comprises a scintillator 129, a fibre optic taper bundle 130 and the associated CCD headboard 124. Fibre optic taper bundles are employed in order to reduce the image size and project the image from the scintillator onto the discrete CCD'S (each camera has an active area which has a parallelogram shape in plan, so that the coverage of adjacent cameras overlaps in a direction transverse to the direction of scanning).

Figure 9 shows the front face of the camera array schematically illustrating the parallelogram shape of each camera's active area and the resulting overlap in a narrow transition zone 174 transverse to the scan direction. Multiple cameras are butted together in order to obtain a composite detector which is approximately 700mm wide. All the cameras have an identical parallelogram shape to ensure that the scanned image does not contain any blank areas. The gaps between the cameras are also minimised to approximately 50 micrometers in order to reduce the amount of information lost in the joints. The scanned area covered by each camera overlaps with the area scanned by the adjacent cameras to ensure that no information is lost. The overlapping images are combined into one image using software, once the data reaches the image pre-processor (described in detail below). Any other artefacts, such

as image distortion or X-ray intensity fluctuations, can also be compensated for in the image pre-processor.

Each X-ray camera 122 detects X-rays which are transmitted through the patient and converts them to an analog electronic output signal. This output signal is amplified by the respective CCD headboard 124 which is mounted directly on the X-ray camera. The gain through the analog path is variable to enable compensation for variable signal intensity. The X-ray signal intensity may vary as a result of fluctuations in the scanning speed, ripple in the X-ray tube's power supply or imperfect X-ray tube parameters. This gain is controlled by control signals from a controller 132 (shown in Figure 10).

After amplification and offset adjustment a standard correlated double sampling (CDS) procedure is performed on the signal by a CCD analog processor (CAP) (not shown). The CAP further converts the analog CDS signal to a digital signal (containing the image data) of 14 bit depth, for example. The digital signal is routed via a ribbon cable to the front end processor 126.

The amplification, offset adjustment, CDS and digitisation should all be performed with low noise electronic circuits to minimise the amount of noise added to the image signal.

The CCD's are operated in a Time Delay and Integration mode in order to obtain maximum benefit from the drift scanning operation. The CCD pixels are clocked at a rate which corresponds to, and is derived from, the scanning speed of the C-arm 16. The digital timing signals are generated in the front end processor 126 in a Digital Programmable Block 134 (see Figure 10). These timing signals are synchronized to the rest of the system by using the C-arm encoder clock signal 136, which is generated by the physical movement of the C-arm. Alternatively, if the movement of the arm can be controlled to be stable

and predictable within the accuracy of the system, then the C-arm encoder-derived clock may be replaced with a precision reference clock circuit.

The C-arm encoder clock 136 needs to be conditioned depending on what format the output from the C-arm movement encoder will be, in order for it to be compatible with the digital signal levels used on the front end processor 126. A clock conditioning circuit 138 ensures this.

Feedback of the beam width is provided to the front end processor 126 and an image pre-processor (see Figure 12). The front end processor 126 uses the beam width feedback to determine which cameras are exposed. The front end processor then activates only exposed cameras, thereby reducing the heat generated in the detector and the data rate on an optical fibre link to the image pre-processor. The image pre-processor uses the beam width feedback in the image processing calculations.

The CCD's of each CCD headboard consist of multiple rows and columns of pixels. Pixel rows are orientated perpendicular to the scanning direction. Electrons generated by X-rays are integrated in the pixel well during the time delay between the pixels' phase clocks, and are moved to the next row by the phase clocks. In each subsequent row additional electrons are generated by X-rays and the image exposure period is thereby lengthened. Image smear is prevented by clocking the pixels in accordance with the mechanical movement of the C-arm holding the X-ray source, as mentioned above. The signal is therefore integrated over the whole height of the X-ray fan beam and no X-ray signal is wasted.

Binning occurs where the values of two or more pixels are combined or added together. For example, two pixel by two pixel binning will produce a super-pixel that is the sum of four adjacent pixels. Vertical pixels (direction of scan, or y-axis) are binned in the CCD's 122, and horizontal pixels (perpendicular to

direction of scan, or x-axis) are binned in the electronics of the front end processor 126 or the image pre-processor.

Binning of CCD rows is performed to increase the signal to noise ratio and to obtain the maximum required pixel size. If the rows were not binned it would increase the CCD readout noise present in the image. This binning of CCD rows is performed in the output registers of the CCD's 122 and is controlled by a programmable digital block 134.

It will be appreciated that, notwithstanding the above described specific configuration, the system may be designed in such a way that binning can occur flexibly either in the CCD or its readout hardware before any digitisation occurs, or once digitised, by software. The binning process may take place in combinations of rows or columns.

Although the front end processor 126 has many functions, three performance related specifications are critical to the final product. These are the speed at which the image information can be read out of the CCD, the data rate between the front end processor 126 and the image pre-processor, and the signal to noise ratio of the system. In a prototype system, the fastest scanning speed was found to be ten seconds for a full body scan (1800mm). Each CCD must have its contents cleared, digitised and multiplexed at the scanning rate. The data rate between the front end processor and the image pre-processor will be determined by the smallest binned super-pixel which is a 2x2 binned pixel (see above for an explanation of pixel binning). This translates to a data rate of 147 Mbits per second, for all twelve channels.

Referring now to Figure 10, the front end processor 126 comprises a digital programmable block 134 which consists of one or more FPGA's and the required memory.

The programmable digital block 134 samples the 14 bit digital signal from the CCD headboards. Binning up to the specified number of columns (typically between 1 and 5) is performed on the digital signal. Combined with the binning of rows in the CCD, as explained above, this gives rise to super-pixels with increased signal to noise ratio, which still maintains the pixel-size required for optimum resolution.

The programmable digital block 134 also generates CCD drive signals. These signals are level shifted on the CCD headboards to the appropriate levels to drive the CCD. The CCD operating voltages are generated in an external power supply. The CCD drive signals and operating voltages are then fed to the CCD headboards through a suitable cable.

The controller 132 mainly controls the different modes of operation of the front end processor 126 and also serves a built-in-test purpose, in terms of which monitors voltage levels and the basic functions on the processor PCB. The test status is reported back to the user interface through an interface 142, which could be an RS232C interface, for example. The controller also controls the different configurations of the programmable digital block 134. This is done by configuring the FPGA's differently each time a different mode of operation is required. This is necessary when different scanning speeds are selected and to perform alignment correction on the data. Feedback from the X-ray beam width control and the shutter are also fed to the controller 132. The controller 132 would typically be implemented using a microprocessor.

The X-ray intensity feedback signal is converted to a digital signal by an A/D converter 144. This signal is appended to each line or horizontal row of image data which is sent to the image pre-processor.

The circuit includes an oscillator 146. The oscillator output is a clock frequency which is very stable over a time period of one scan. The clock signal from the

C-arm encoder is compared to this frequency. The result of the comparison indicates the variation in speed from the C-arm. This result is also appended to the each horizontal row of image data sent to the image pre-processor. The image pre-processor uses the intensity and speed variation information appended to each line to correct for the uneven illumination due to variations in the speed of travel of the C-arm. The oscillator also clocks the electronic circuits when the C-arm is not moving.

The image pre-processor is used to convert the image data output of the front end processor 126 into a form which can be displayed on a video monitor. The signal from the front end processor is a multiplexed data signal generated from the twelve individual data output signals from the respective CCD headboards 124. The overall block diagram illustrating the image pre-processor's hardware and software interfaces is shown in Figure 11, while Figure 12 is a schematic diagram of the image pre-processor, which is typically implemented in a personal computer 152.

As shown in Figures 11 and 12, the fibre optic data link output 150 of the front end processor 126 (see Figure 10) is connected to a databus and fibre optic interface controller circuit 154 which converts the optical signals back to a digital electronic form. The signals are fed via the personal computer's databus to a random access memory (RAM), for processing by either the standard microprocessor or a dedicated digital signal processing (DSP) circuit. Once in RAM, the image correction task manipulates, corrects and converts the digital data into a form which can be transmitted to a diagnostic viewing station 36 via the database interface library 164.

The image pre-processor (IPP) consists of seven main functional blocks. Four of these control or provide access to interface points, whilst the other three provide the core functionality of the IPP. Referring to Figure 11, these items are the IPP system manager 156, which controls the state and mode of the

IPP. An image correction and enhancement task/thread 158 performs all the image corrections and enhancements. A confirming image generation task/thread 160 generates a confirming image, which is sent to the operator console 28. A front end processor (FEP) serial communications manager 162 handles the serial interface to the front end processor 126. This interface could be a standard RS232C link. The databus and fibre optic interface controller 154 handles the set up of the fibre optic interface and, depending on what driver support is provided by the manufacturer, handles the functionality to read data from this interface. A database interface library 164 handles all the interface requirements to an image database server and the diagnostic viewing stations 36. Finally, an interface to the operator console 166 handles the interface to the operator console 28.

The image pre-processor (IPP) processes the image data and corrects this data for imaging artefacts. The following performance factors are critical to the final product and the achievement of the IPP's main purpose:

FEP/IPP Fibre Data Link – The smallest binned super-pixel is at least a 2x2 pixel binning. This translates to a data rate of 147 Mbits per second, for all cameras. The data link is able to sustain this transfer rate during the scan operation, and transfer this data into the IPP system memory in real-time.

Correction speed – The image is corrected as close to real time as possible. The correction algorithms ensure that a corrected and a confirming image is available to the operator at the operating console 28 and the diagnostic monitor 36 as soon as possible.

Image Size – The IPP keeps at least one copy of the full image in memory whilst performing the correction algorithm, and requires enough memory to do so.

Now described in detail are the image corrections performed on the images by the image pre-processor. These corrections are performed to compensate for the artificial elements that are added to a picture during digital capture and display. They are also aimed at removing artifacts caused by the butting of the cameras and the fibre optic tapers. The image corrections must be performed in a specific order, which is determined by the effect expected from a specific correction. A flow chart of the image corrections is shown in Figure 13.

A standard sequence of corrections is:

1. y-alignment
2. x-alignment
3. CCD dark current subtraction (dc-offset subtraction)
4. signal normalisation (gain compensation)
5. compensation for scan speed variations
6. compensation for x-ray intensity fluctuations
7. scaling of image (for example, logarithmic)

Certain of the corrections may be left out of the sequence if their contribution to image quality is not warranted by the expense of processing speed.

The first correction performed is ***y-alignment***. This correction compensates for the slight difference in positioning of the cameras in the x-y plane. A separate y-alignment value is defined for each pixel instead of for each camera. As the fibre optic tapers can cause bow distortion of the image, defining a separate value for each pixel instead of for each camera allows the bow distortion to be compensated for, hence the need for separate values for each pixel as opposed to per camera. This translates to a vertical shift of image values. This correction should take care of the problem illustrated in Figures 14(a) and (b). A facility is also provided to allow the user to edit the compensation values of the final curve.

The second correction is a ***butt*** or ***x-alignment*** correction. This can only be performed once the pixels have been appropriately aligned in the y-direction and it therefore follows the y-alignment. The fibre optic tapers used are parallelogram in shape which results in an overlap of pixels at the join of two tapers. There is also some portion of the CCD that is not covered by a taper. This results in dark or unexposed pixels on either side of the tapers. The unexposed pixels lying at the ends of each taper will be eliminated in the front end processor 126 during binning. Hence the correction software need only concern itself with the overlapped values created by the butting.

Suppose that camera n and camera n+1 overlap by t_{n0} pixels, as shown in Figure 9. The overlap is compensated for by adding the values of the overlapping pixels ie. the first t_{n0} pixels of camera n+1 are added to the last t_{n0} pixels of camera n. This caters for the problem illustrated schematically in Figure 15.

The next two corrections are standard ***gain*** and ***offset*** compensations. Once again a separate offset and gain value is used per column and not per camera.

The dark current level or dc offset value is determined during calibration before the scanning of each image starts, to compensate for temperature drift in the CCD. This is done by obtaining an image without exposing the detector with X-rays. An average signal level is calculated for each image column and this constitutes the dc offset value. Each column in the image is then corrected for the dc offset by subtracting the corresponding dark current offset value for that column from each pixel in that column.

The gain mask is also determined during calibration. This mask does not need to be determined during every scan, but rather during scheduled calibration sessions. The raw gain mask is obtained for every X-ray energy, by exposing

the camera with an uninterrupted beam of X-rays and averaging the image per column. Thereafter the offset mask is subtracted from the gain mask and the result becomes the final gain mask. Each column in the image is normalised for the corresponding gain by dividing each pixel by the corresponding value in the gain mask. Figure 16 shows the flow diagram for determination of the coefficients to be used during compensation.

Similar to the gain mask compensation is the compensation for scan speed variations and for X-ray intensity fluctuations. Variations in the scan speed and X-ray intensity effectively cause gain variations per row in the image. The change in gain is proportional to the change in speed or intensity and the image can be normalised per row with respect to these variations.

The above steps are carried out as follows:

Step 1: Measure the dark current with the X-rays off.

Step 2: Acquire image gain when the X-rays are turned on.

Step 3: Subtract the dark current from the image.

Step 4: Normalise the image using the gain factors determined from the gain mask, X-ray intensity and speed variations.

The final correction of the image is the logging of the corrected value. This is necessary because X-ray attenuation is exponential. The required log values are obtained by means of a predefined look-up table which is generated during initialisation time and remains in memory for usage thereafter. The log values are calculated in such a way as to provide for conditioning of the image as well as logging it. The values in the look-up table would range from 0 to 16384 if a

14 bit range is utilised. These corrections must be performed as fast as possible in order to adequately cope with the demands of a trauma unit.

The algorithms used to perform the abovementioned corrections have been highly optimised to improve the performance and speed of the system. The algorithms have been implemented as a multi-threaded process, with multiple tasks running concurrently. This process consists mainly of three tasks:

1. The main task receives image information and only begins performing the abovementioned corrections after the maximum number of rows that could be misaligned has been received. (The reason for waiting for the maximum number of rows that could be misaligned before starting the corrections is to ensure that the linear shifts performed by the y-alignment do not go out of scope.) This thread is given critical priority to ensure that the corrections are performed as fast as possible.

2. A contrast enhancement task begins processing the image as soon as there are corrected rows available from the main task. This task performs the so-called "unsharp mask" operation (basically a contrast enhancement, grey-scale compression and edge enhancement algorithm) on the corrected rows. This task makes use of a kernel, which is a square matrix, and convolves this matrix over the corrected rows to produce an "unsharp mask" image. This image forms the basis of the confirming image displayed on the operator's console.

3. A reduction task reduces the image produced by either of the above tasks to generate a pictogram of the radiograph (image) taken. The reduction factor is normally set to 12, but is

dynamically configurable depending on the size of the image taken.

Tasks 2 and 3 above are used interchangeably depending on the customer's requirements. Normally an "unsharp mask" image is generated as a confirming image, and a reduced version of this is used as a pictogram for later selection on the database. This setup is interchangeable, allowing a reduced radiograph to become a confirming image and an "unsharp mask" version of this then becoming the pictogram.

Apart from these main tasks, there are miscellaneous tasks which perform the following functions:

a) Conditioning of the "unsharp masked" image. Under conditioning the following is understood:

- floating point values are converted into 8-bit integer values,
- range is adjusted for optimal viewing scale (adjusted to fit into 8-bit scale according to max/min values) and
- erratic data (eg. negative values) that does not contribute to the picture is removed (adjusted to max/min values).

b) Removal of unexposed columns (these are created by clocking all the columns in the CCD's regardless of whether or not they lie within the scope of the collimator settings, because CCD's cannot be read out only partially).

c) The transmission of both the corrected image and confirming image to the database and the operator console respectively.

Illustrated in Figure 17 in more detail is the system manager 156, which is responsible for controlling the state, mode and operation of the image capture system.

The system manager 156 consists of three processes:

- An operations controller 168, which manages the general operation of the image capture system. The operations controller also controls the correction, calibration, and confirming image generation processes;

- An alarm and status handler 170 which manages the alarm and status database as well as the alarm history; and

- A message handler 172 which manages all messages that are posted to the IPP mailbox, and posts all responses to the relevant mailboxes.

Figure 18 shows the image pre-processor state machine as controlled by the system manager 156. After initialisation, the system manager remains in a disconnected state until the operator console 28 and the image database server connect, and establish the relevant communication channels. The image pre-processor is then available and ready for use. The front end processor 126 does not need to be connected, or be communicating at this phase. This allows the front end processor to enter a power saving mode.

It is the responsibility of the image pre-processor to begin communication with the front end processor, so that it may wake-up from the power saving mode and begin activation and preparation for a scan. The operator console will notify the image pre-processor that a scan is about to begin, and that the

image pre-processor needs to prepare for a scan. The image pre-processor immediately communicates over the serial link to the front end processor, thus waking up the front end processor from the power-saving mode and causing it to connect and communicate with the image pre-processor. Once a valid response has been received from the front end processor, the image pre-processor enters the active state waiting for a scan-activate notification from the operator console. The image pre-processor then undergoes the scan process. On termination, it reverts to the standby state.

Thus it can be seen that the invention provides an alternative apparatus which can produce images of medical diagnostic quality at relatively low radiation doses.

CLAIMS

1. Imaging apparatus comprising:

   a radiation source for generating an imaging beam;

   a camera array comprising a plurality of cameras responsive to the imaging beam and arranged adjacent one another, each camera having an output for generating image signals;

   drive means for moving the radiation source and the camera array relative to a subject;

   signal processor means arranged to receive image signals from the data output of each camera and to generate composite image data therefrom;

   memory means for storing the composite image data;

   output means for displaying an image generated from the composite image data; and

   control means responsive to the image signals and/or the composite image data to control the operation of the drive means according to the intensity of the imaging beam.

2. Imaging apparatus according to claim 1 wherein the radiation source is an X-ray source and the cameras comprise scintillators and associated charge-coupled devices for generating digital image data signals.

3. Imaging apparatus according to claim 1 or claim 2 wherein the camera array is arranged so that fields of coverage of adjacent cameras overlap in a direction transverse to the direction of movement of the camera array, so that the camera array provides full coverage of an elongate imaging zone defined thereby.

4. Imaging apparatus according to claim 3 wherein each camera has an active area with a parallelogram shape, with adjacent ends of the respective active areas abutting, so that the coverage of adjacent cameras overlaps in a relatively narrow transition zone extending transversely to the direction of scanning.

5. Imaging apparatus according to claim 3 or claim 4 wherein the signal processor means comprises a digital signal processor arranged to apply a compensation algorithm to the image data signals to compensate for relative misalignment or distortion of the cameras.

6. Imaging apparatus according to claim 5 wherein the compensation algorithm is arranged to compensate for misalignment of each image pixel with respect to both x- and y- axes, the y-axis corresponding to the direction of scanning and the x-axis being transverse to the direction of scanning.

7. Imaging apparatus according to claim 6 wherein the compensation algorithm is arranged first to compensate for errors in the positioning of pixels in the direction of the y-axis, and then in the direction of the x-axis to compensate for unexposed and overlapping pixels in the transition zones between the cameras.

8. Imaging apparatus according to any one of claims 1 to 7 wherein the control means is arranged to measure variations in the intensity of the

imaging beam, and to generate drive control signals to vary the speed of the drive means, to maintain the effective intensity at a constant level.

9. Imaging apparatus according to any one of claims 1 to 7 wherein the control means is arranged to carry out intensity compensation by means of software correction of the image data signals using measured information regarding intensity fluctuations in the imaging beam.

10. Imaging apparatus according to any one of claims 1 to 9 wherein the drive means has an encoder associated therewith for generating clock signals related to the movement of the radiation source and the camera array, and the control means includes a clock conditioning circuit responsive to the clock signals to generate timing signals which are used to synchronise the imaging operation of the camera array with the movement thereof.

11. Imaging apparatus according to any one of claims 1 to 9 wherein the control means includes a reference clock circuit which is used to generate timing signals for controlling both the operation of the drive means and the camera array, so that the imaging operation of the camera array is synchronised with the movement thereof.

12. Imaging apparatus according to any one of claims 1 to 11 wherein each camera defines a plurality of imaging pixels, the outputs of at least some of the pixels being combined according to a predetermined scheme to improve the signal-to-noise ratio of the image signals.

13. Imaging apparatus according to claim 12 wherein the cameras are adapted to combine the outputs of pixels which are adjacent in the

direction of movement of the radiation source and the camera array at the time of generation of the image signals.

14. Imaging apparatus according to claim 13 wherein the signal processor means is adapted to process the image signals to combine the outputs of pixels which are adjacent in a direction transverse to the direction of movement of the radiation source and the camera array.

15. Imaging apparatus substantially as herein described and illustrated.

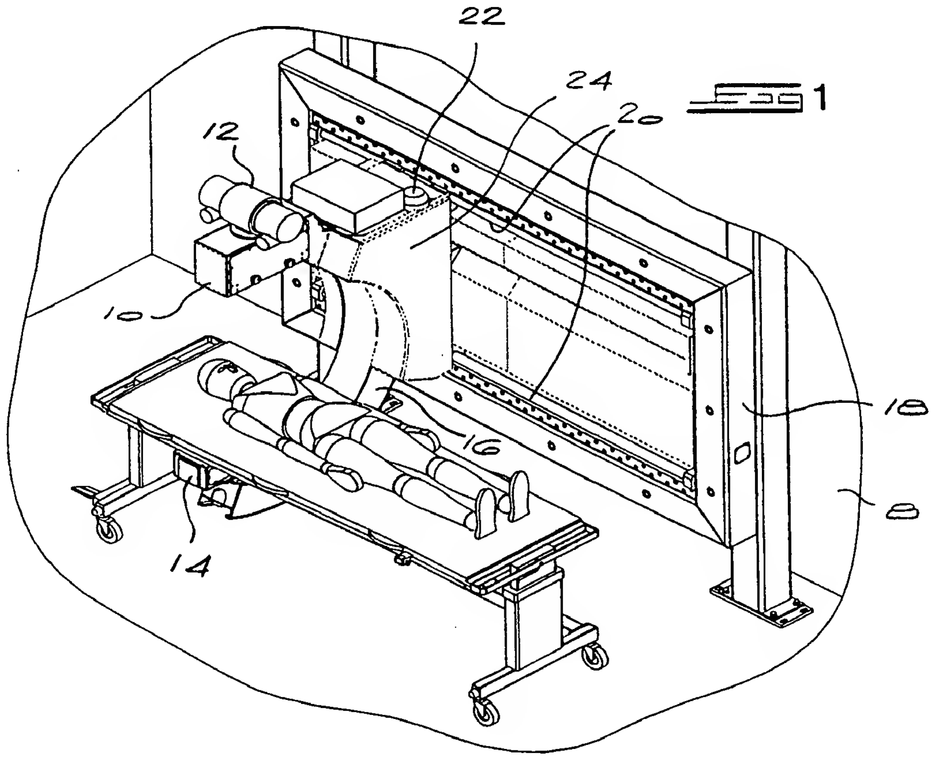


FIG 1

FIG 2

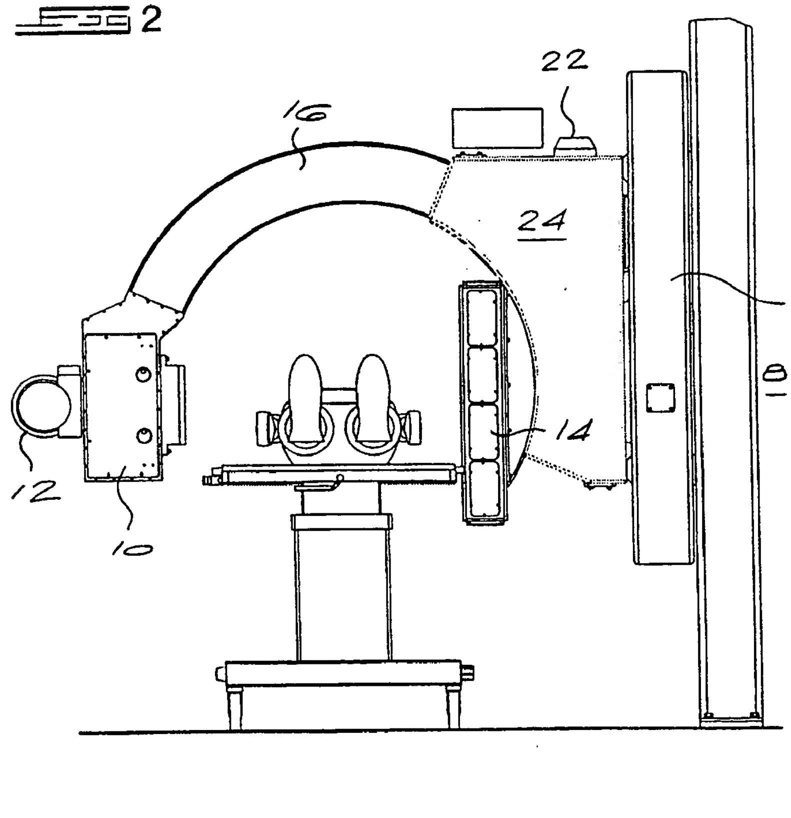
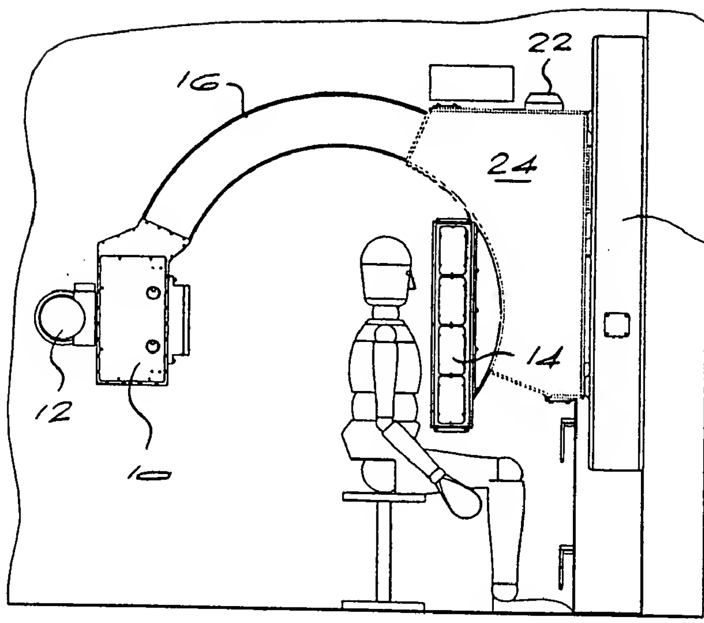


FIG. 3



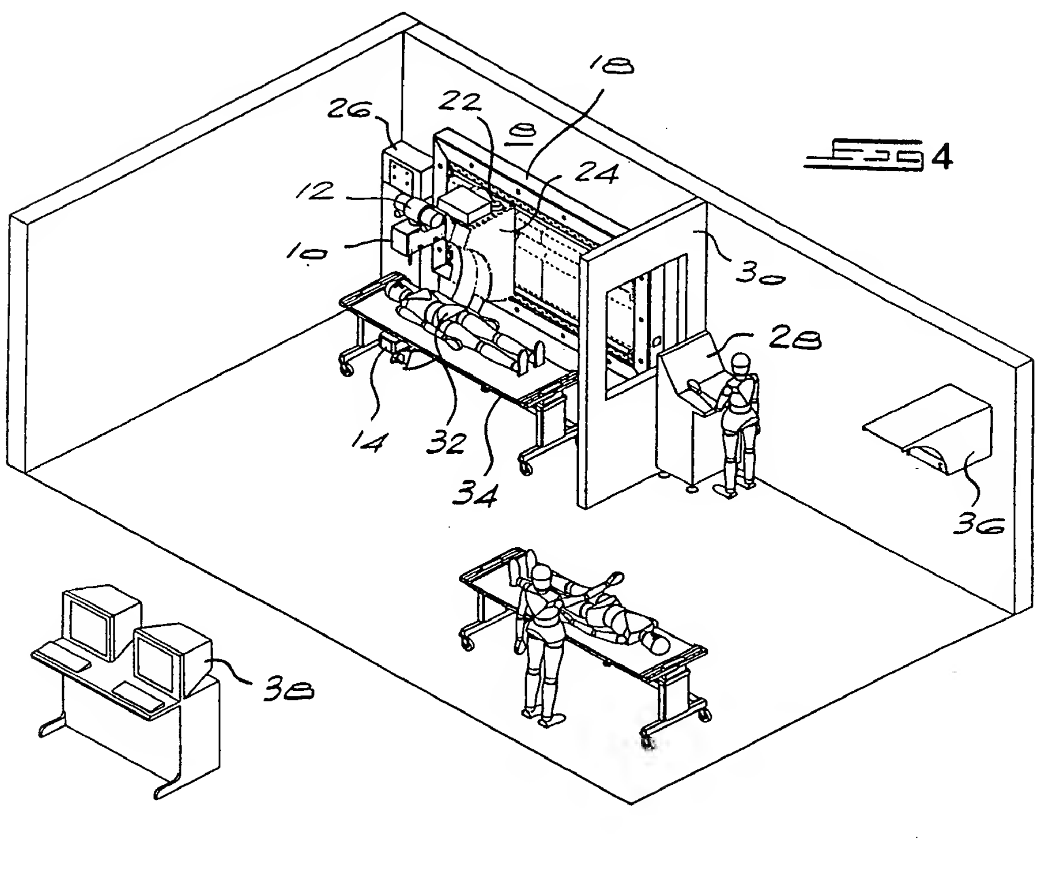


FIG. 4

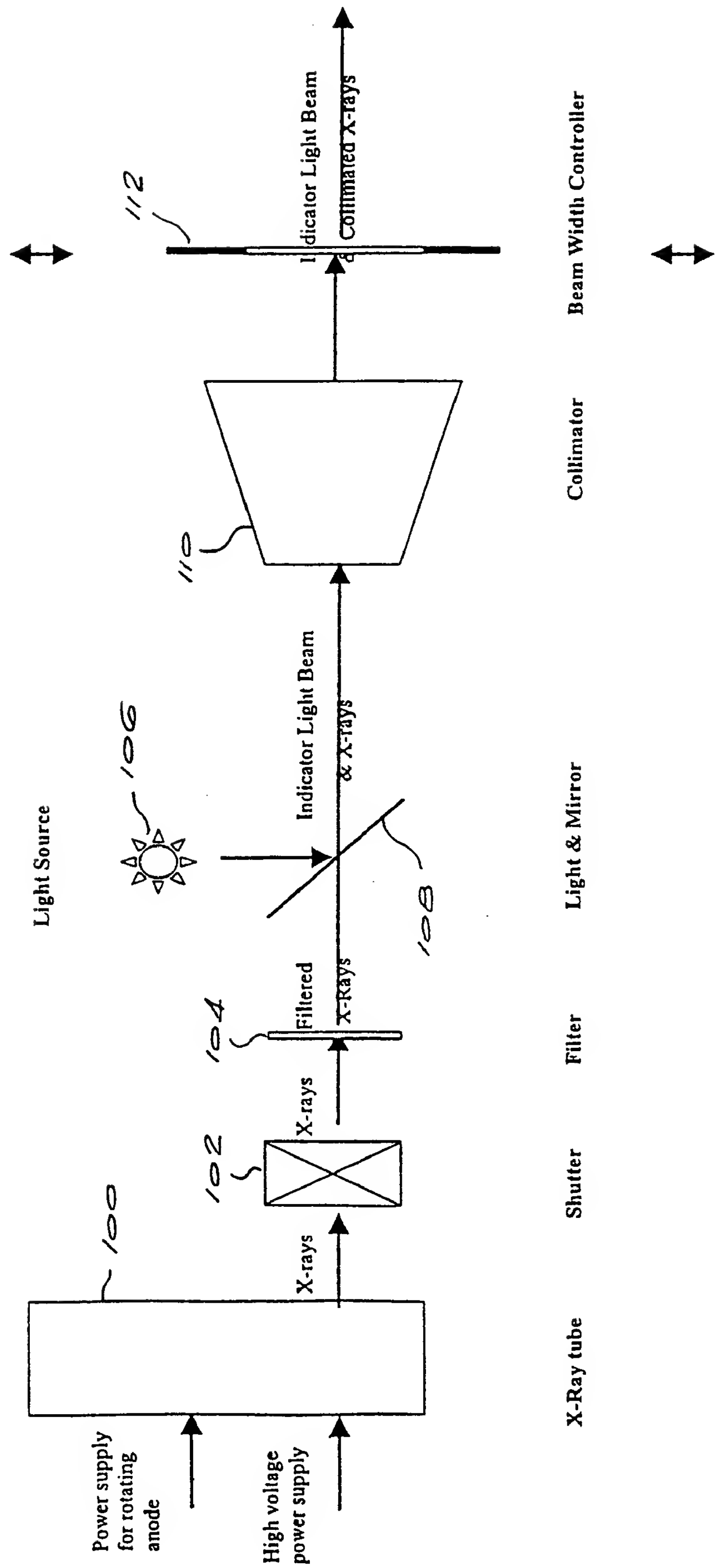

Light Source
106
Power supply for rotating anode
High voltage power supply
100
X-rays
102
X-rays
104
Filtered X-Rays
108
Indicator Light Beam & X-rays
110
112
Indicator Light Beam & Collimated X-rays
X-Ray tube
Shutter
Filter
Light & Mirror
Collimator
Beam Width Controller

FIG 5

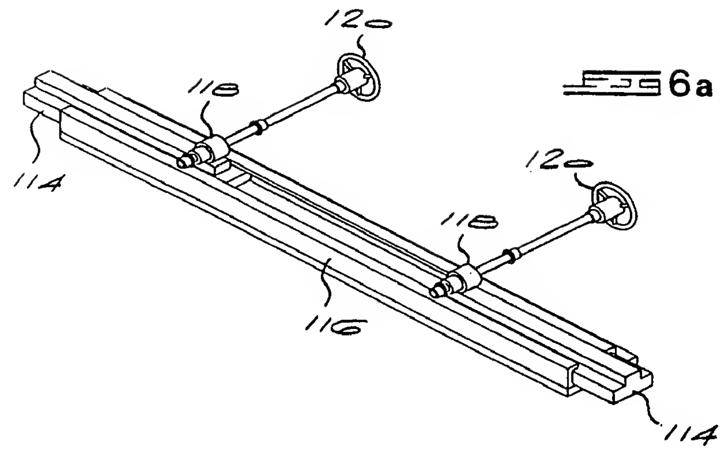


FIG 6a

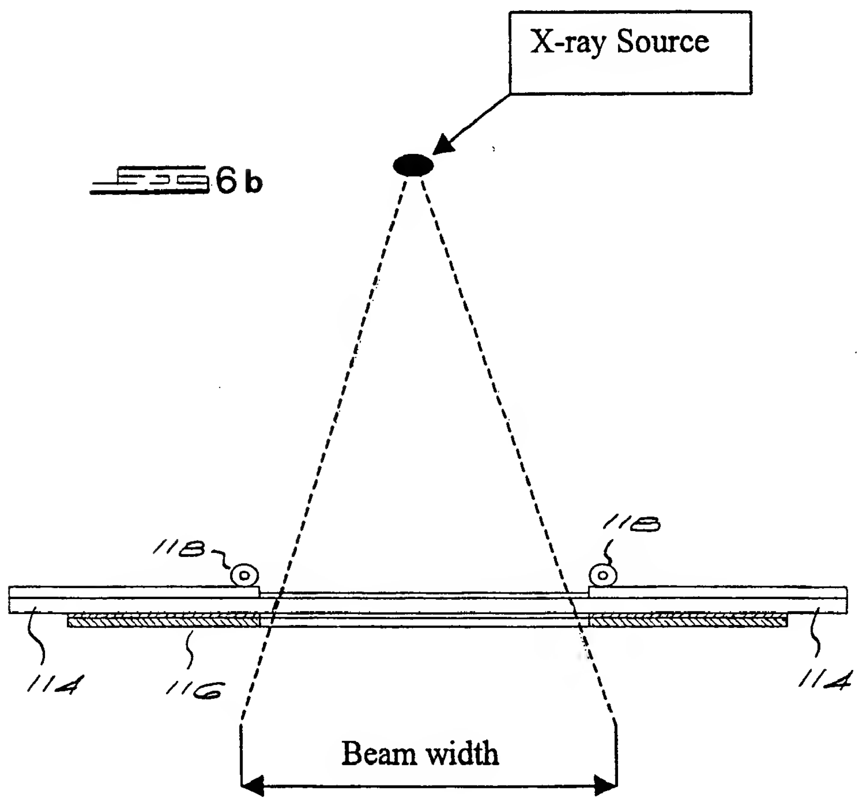


FIG 6b

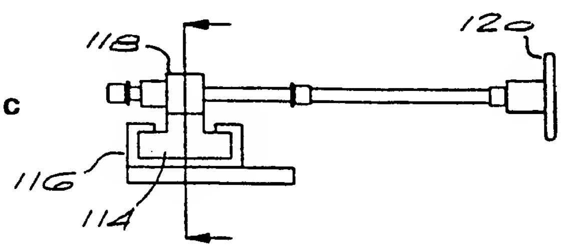


FIG 6c

FIG 7

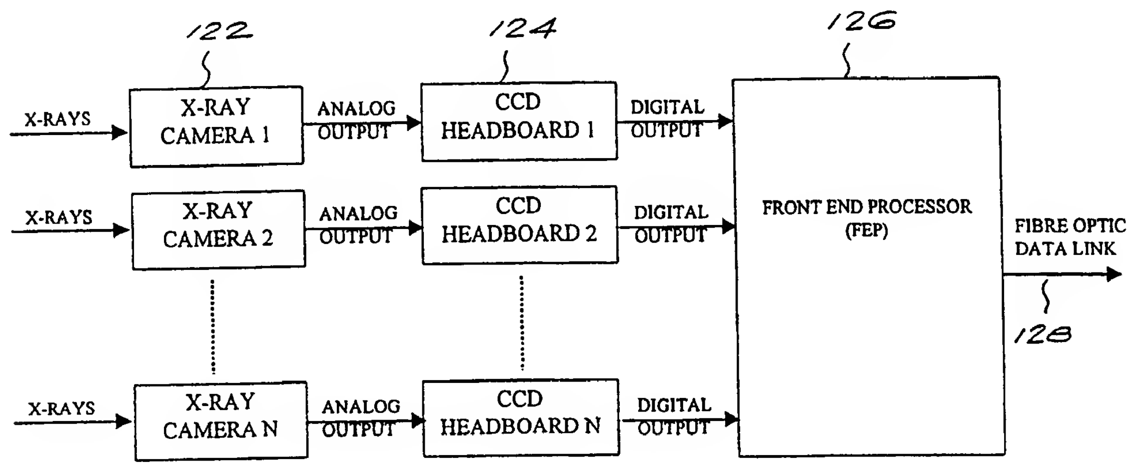


FIG 8a

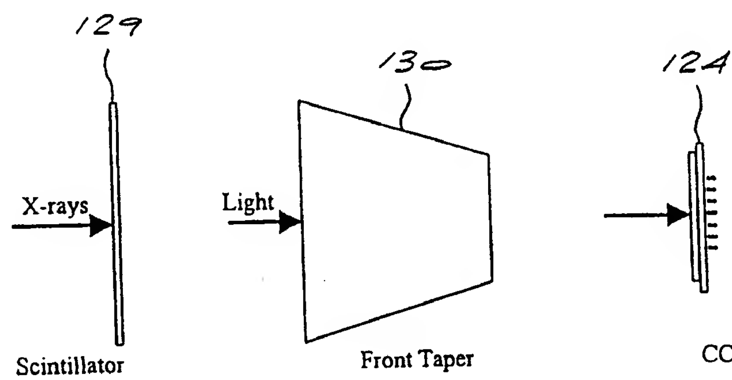
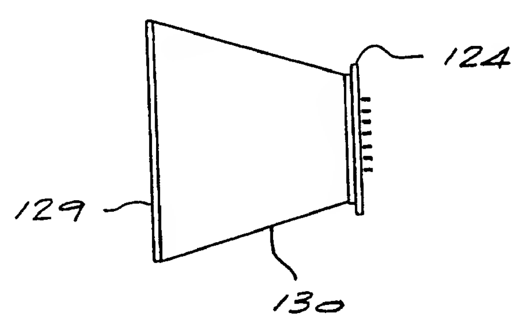


FIG 8b



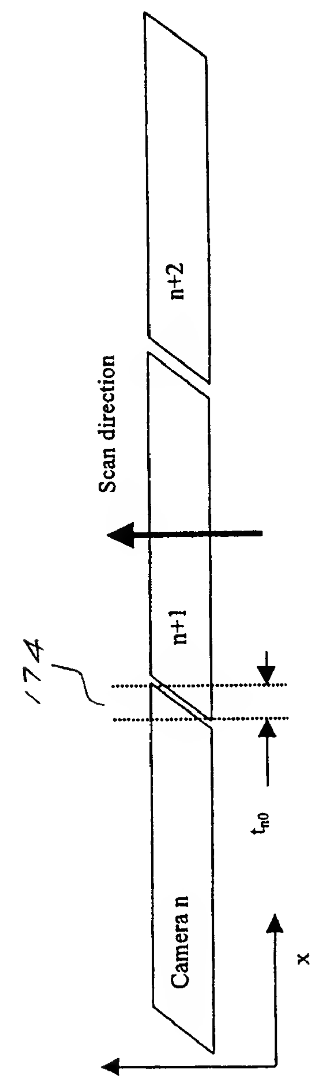

174
Scan direction
Camera n
n+1
n+2
t_{n0}
x
y

FIG 9

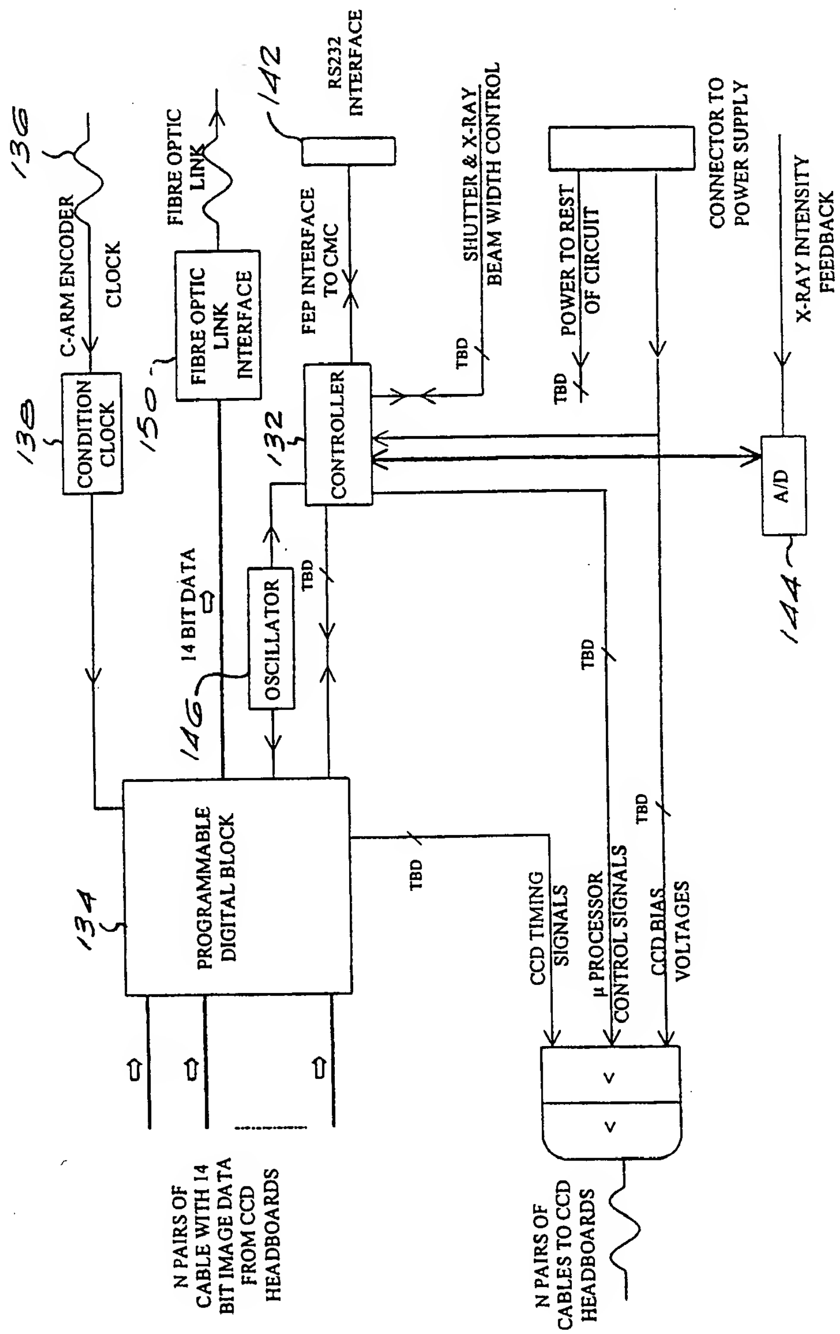

136
C-ARM ENCODER
CLOCK
138
CONDITION CLOCK
FIBRE OPTIC LINK
150
FIBRE OPTIC LINK INTERFACE
142
RS232 INTERFACE
FEP INTERFACE TO CMC
132
CONTROLLER
TBD
SHUTTER & X-RAY BEAM WIDTH CONTROL
POWER TO REST OF CIRCUIT
CONNECTOR TO POWER SUPPLY
X-RAY INTENSITY FEEDBACK
A/D
144
14 BIT DATA
146
OSCILLATOR
134
PROGRAMMABLE DIGITAL BLOCK
CCD TIMING SIGNALS
µ PROCESSOR CONTROL SIGNALS
CCD BIAS VOLTAGES
N PAIRS OF CABLE WITH 14 BIT IMAGE DATA FROM CCD HEADBOARDS
N PAIRS OF CABLES TO CCD HEADBOARDS

FIG 10

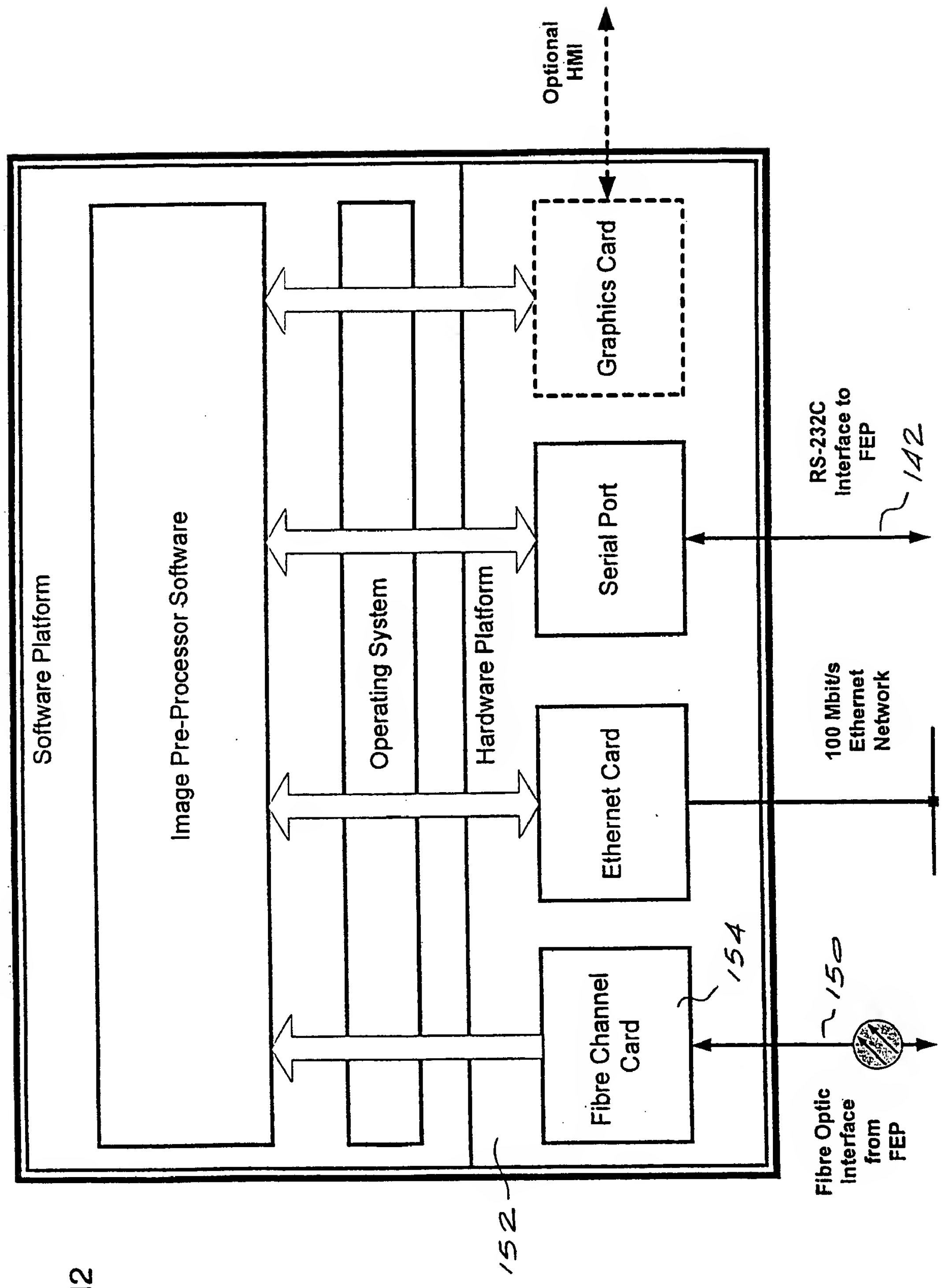

Optional HMI
Software Platform
Image Pre-Processor Software
Operating System
Hardware Platform
Graphics Card
Serial Port
Ethernet Card
Fibre Channel Card
RS-232C Interface to FEP
142
100 Mbit/s Ethernet Network
154
150
Fibre Optic Interface from FEP
152

FIG. 12

FIG 13

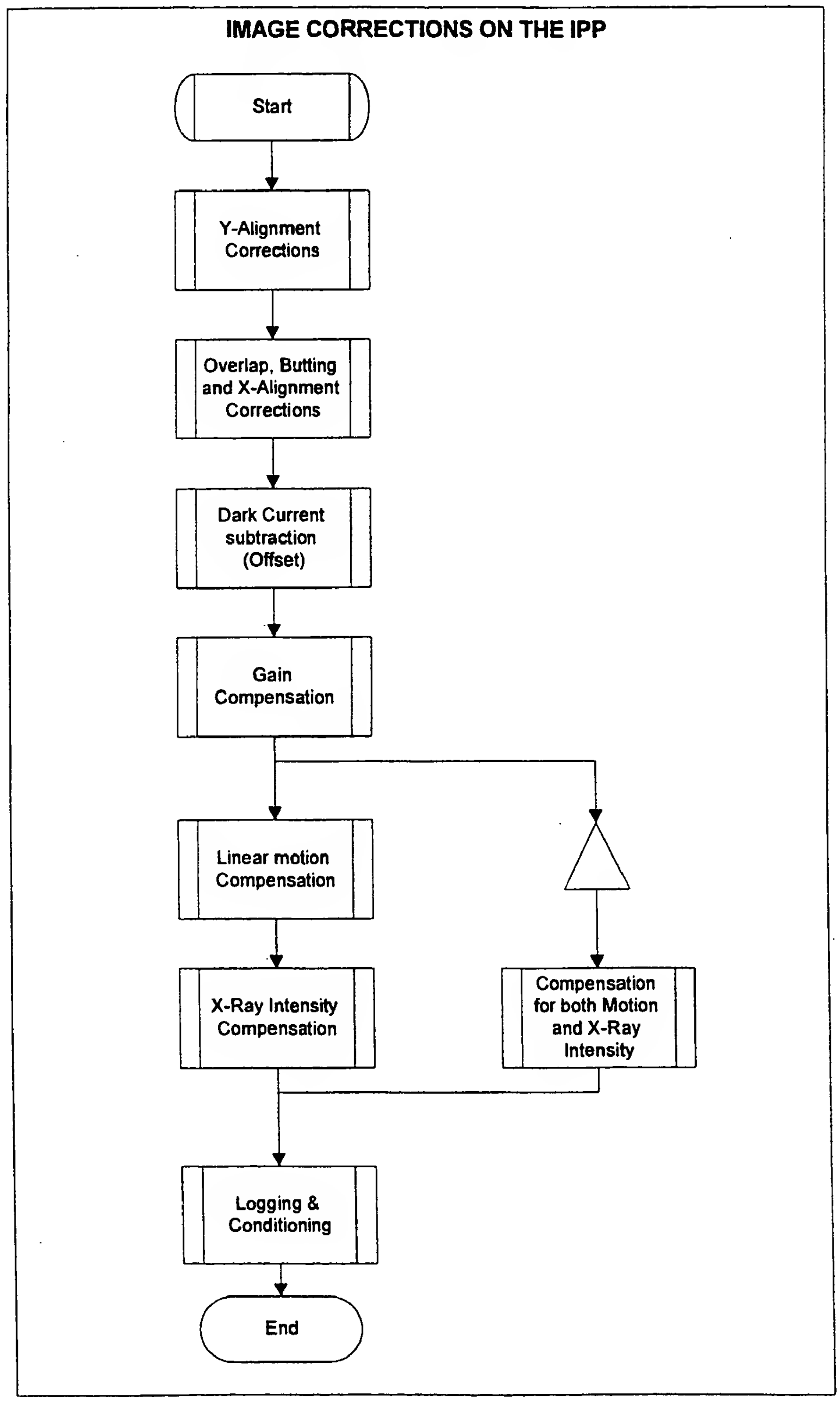


IMAGE CORRECTIONS ON THE IPP
Start
Y-Alignment Corrections
Overlap, Butting and X-Alignment Corrections
Dark Current subtraction (Offset)
Gain Compensation
Linear motion Compensation
X-Ray Intensity Compensation
Compensation for both Motion and X-Ray Intensity
Logging & Conditioning
End

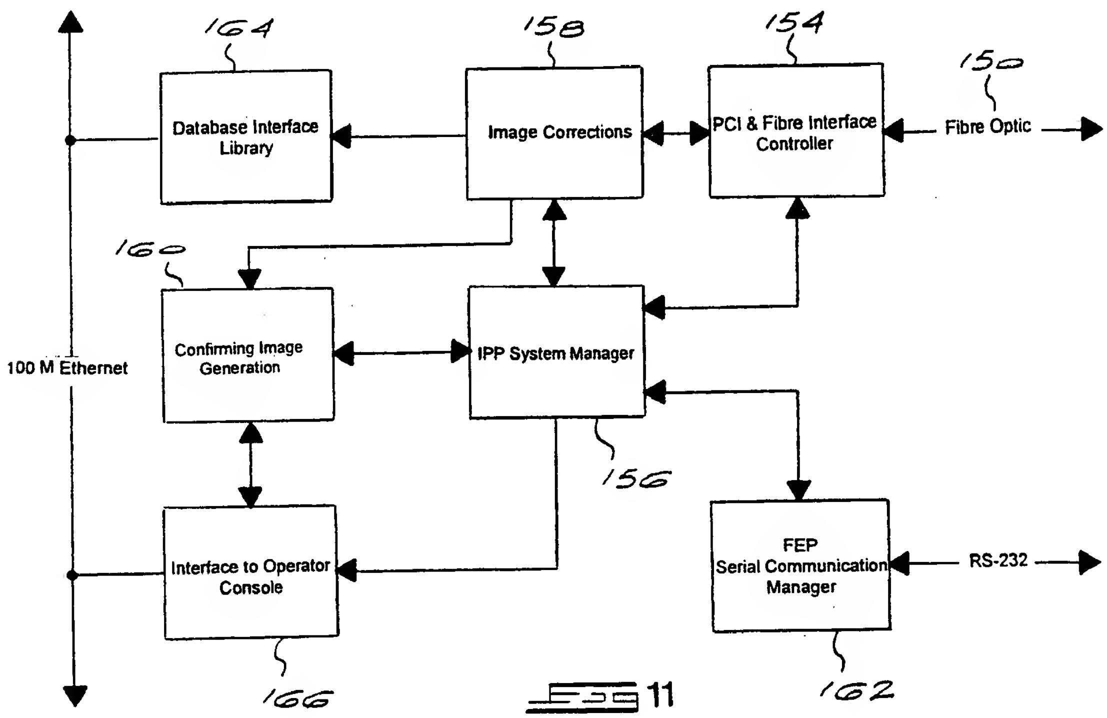


FIG 11

FIG 14a

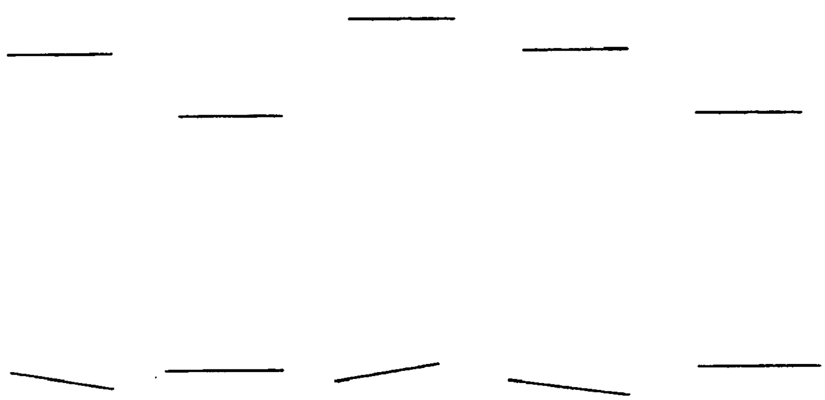


FIG 14b

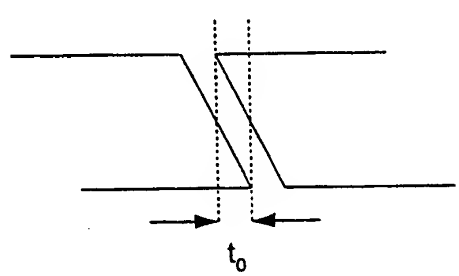


FIG 15

FIG 16

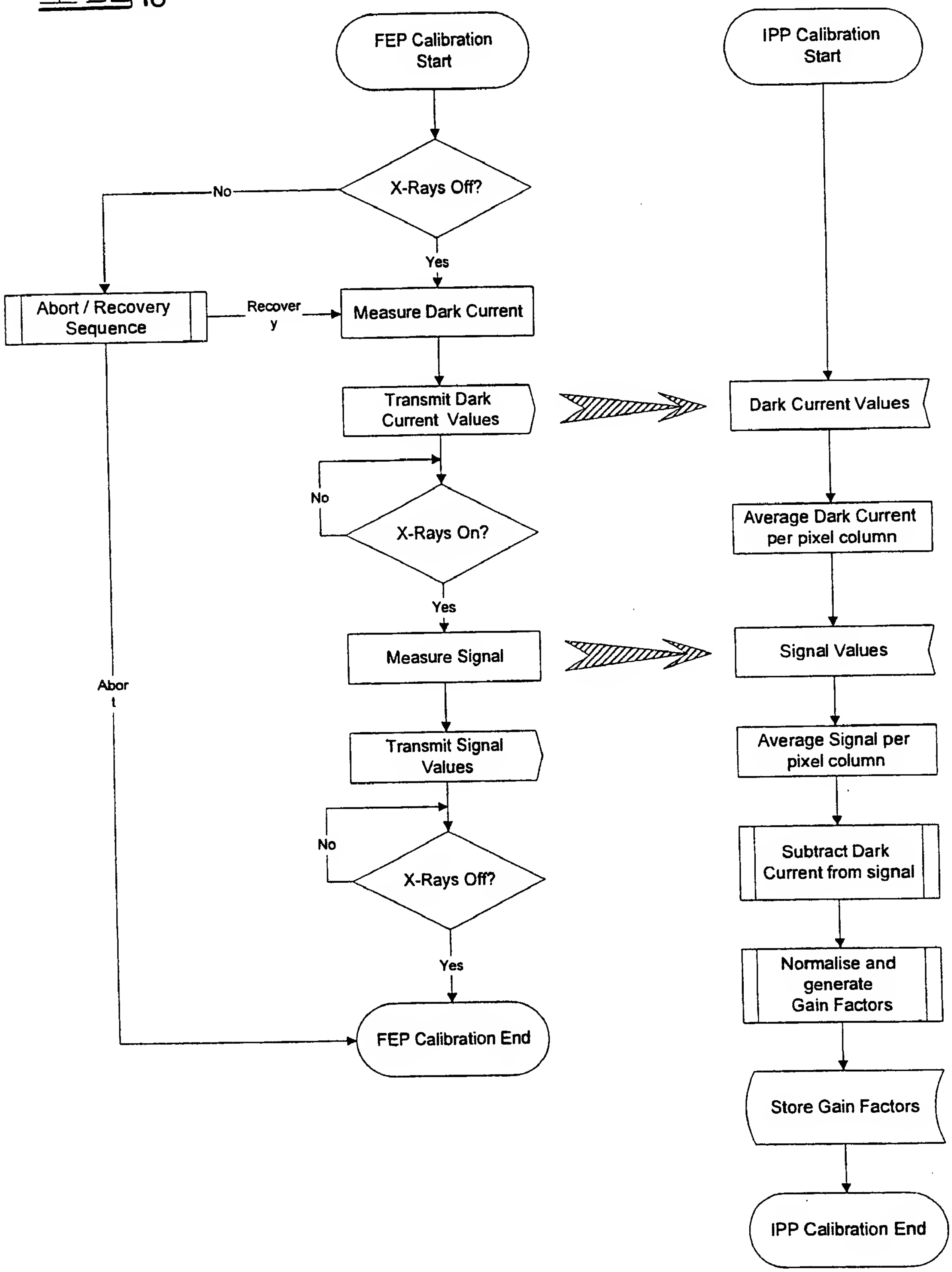

FEP Calibration Start
X-Rays Off?
No
Yes
Abort / Recovery Sequence
Recover y
Measure Dark Current
Transmit Dark Current Values
No
X-Rays On?
Yes
Measure Signal
Abor t
Transmit Signal Values
No
X-Rays Off?
Yes
FEP Calibration End
IPP Calibration Start
Dark Current Values
Average Dark Current per pixel column
Signal Values
Average Signal per pixel column
Subtract Dark Current from signal
Normalise and generate Gain Factors
Store Gain Factors
IPP Calibration End

FIG 17

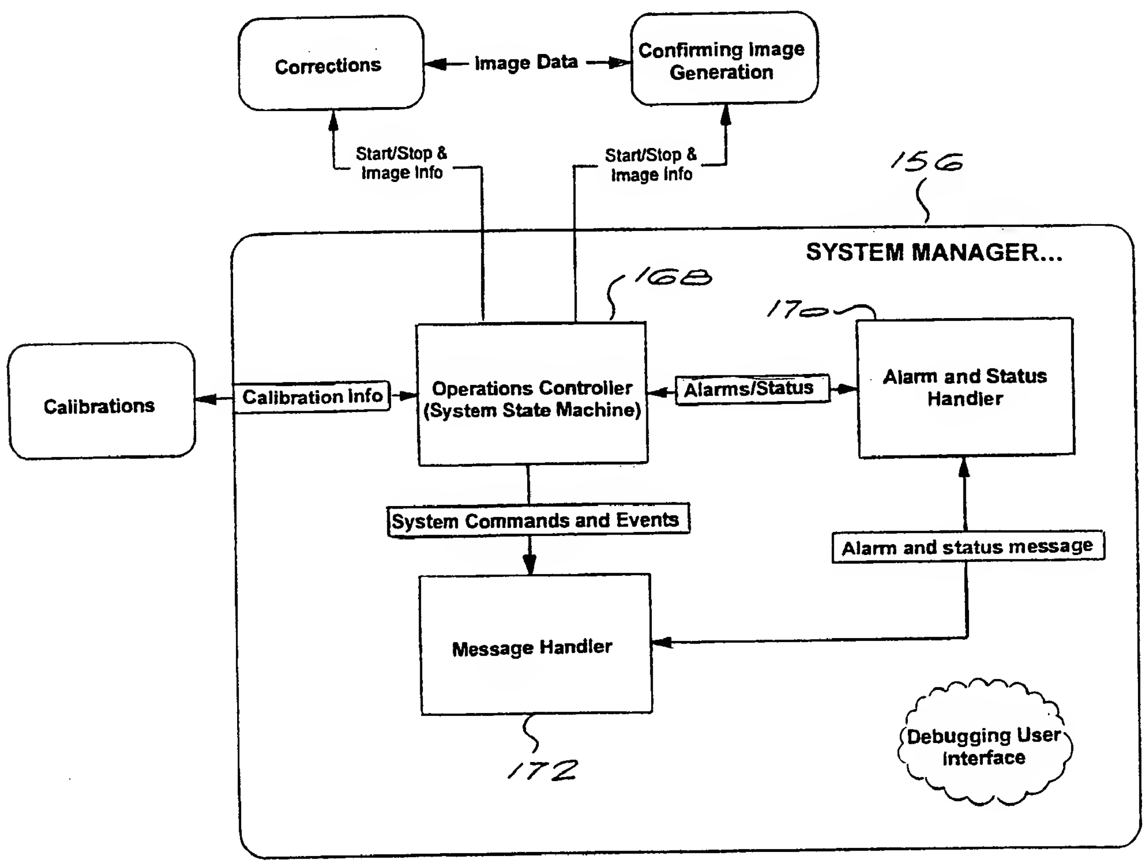
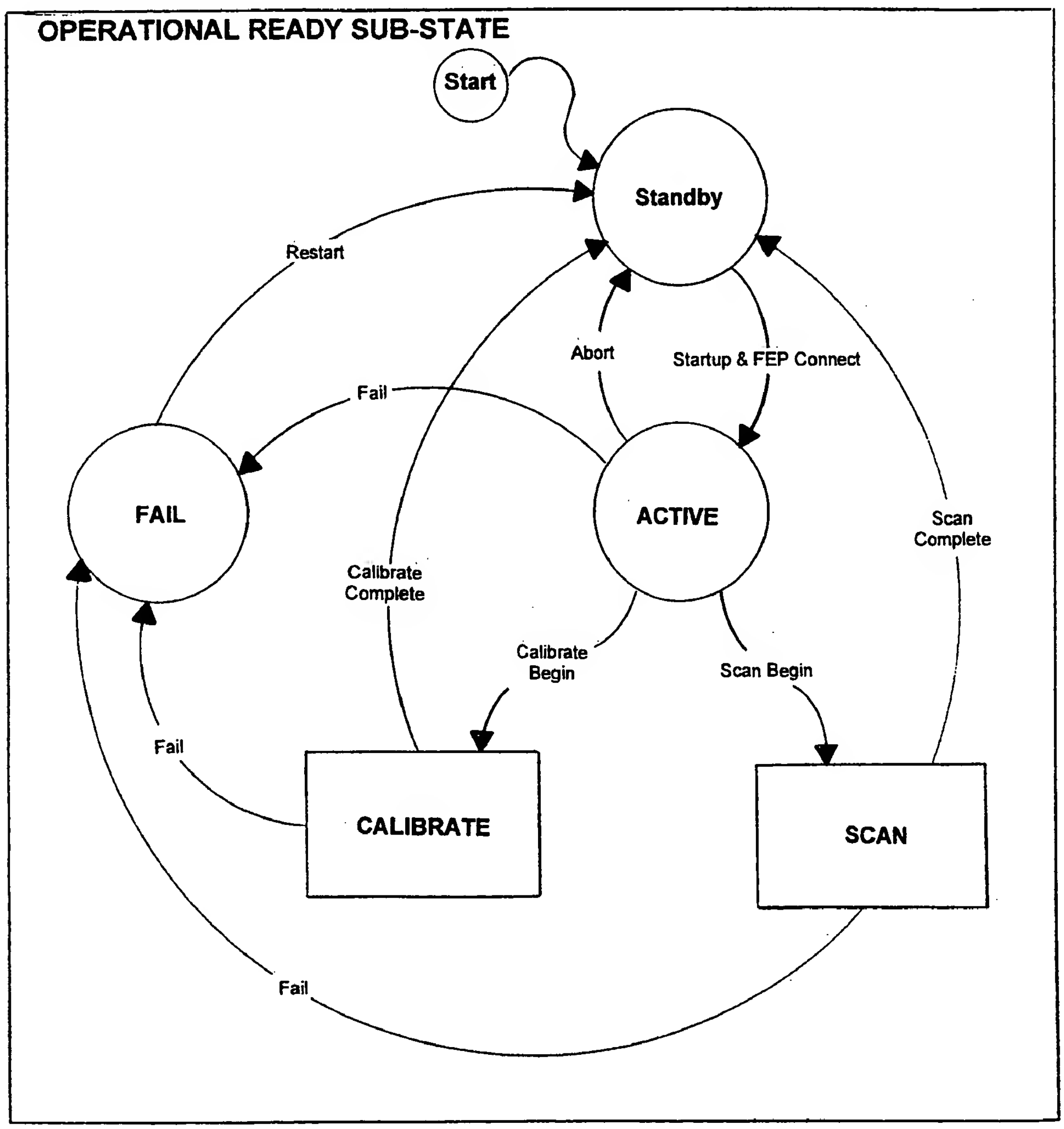

Corrections
Image Data
Confirming Image Generation
Start/Stop & Image Info
Start/Stop & Image Info
156
SYSTEM MANAGER...
168
170
Calibrations
Calibration Info
Operations Controller (System State Machine)
Alarms/Status
Alarm and Status Handler
System Commands and Events
Alarm and status message
Message Handler
172
Debugging User Interface

FIG 18


OPERATIONAL READY SUB-STATE
Start
Standby
Restart
Abort
Startup & FEP Connect
Fail
FAIL
ACTIVE
Scan
Complete
Calibrate
Complete
Calibrate
Begin
Scan Begin
Fail
CALIBRATE
SCAN
Fail

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB 00/00256

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A61B6/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 4 179 100 A (STERNGLASS ERNEST J ET AL) 18 December 1979 (1979-12-18) column 4, line 43 -column 5, line 16 column 12, line 46 -column 13, line 4 column 13, line 52 - line 68 column 15, line 62 -column 16, line 15	1,2,8,9, 15 12
A	DE 35 03 465 A (MORITA MFG) 1 August 1985 (1985-08-01) page 5, line 20 -page 6, line 19 page 9, line 1 - line 25	1,15

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 June 2000	21/06/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Martelli, L

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/IB 00/00256

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		GB 2066016 A,B	01-07-1981
		NL 7909037 A,B,	16-07-1981
DE 3503465 A	01-08-1985	JP 1595851 C	27-12-1990
		JP 2018091 B	24-04-1990
		JP 60160947 A	22-08-1985
		FI 850415 A,B,	02-08-1985
		US 4589121 A	13-05-1986